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Summary of Geotechnical Investigation and Pit Slope Stability Assessment Maria Pit Expansion

October 2015

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October 12, 2015

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Subject: **Summary of Geotechnical Investigation and Pit Slope Stability Assessment – Maria Pit Expansion**

Dear Ms. Swenson:

This document summarizes the results of geotechnical investigation and pit slope stability assessment conducted by **Cardno Inc. (*Cardno*)** for **CS Mining**'s **(*CSM*)** Maria Pit near Milford, Utah. The geotechnical investigation included geological and geotechnical field mapping, reverse circulation drilling, down-hole geophysical logging, and laboratory testing of available core specimens. The stability assessment includes geomechanical characterization of the expected pit walls, assessment of the discontinuities present in the walls of the proposed pit expansion, evaluation of the expected stability of the walls, and summary of potential modes of failure in the walls. Details of the work are available upon request.

We appreciate the opportunity to provide CSM with professional mining services. Please contact us if you have any questions or comments.

Sincerely,

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File: CSM100 - FINAL Summary Report - Maria Pit Geotech (10-12-2015) (ka2 ge pjd).docx

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1 Introduction

Cardno Inc. (***Cardno***) conducted a geotechnical field investigation and slope stability assessment for **CS Mining**'s (***CSM***) Maria Pit area. The document herein provides a summary of the work. Details are available upon request.

Stability assessment for expansion of the Maria Pit is based on geological and geotechnical information collected from field observations and three exploration drill holes. The stability assessment includes evaluation of alluvium slope stability, overall rock mass stability, and stability based on discontinuities in the rock (kinematic). Assessment of stability for slopes constructed in alluvium material indicates that the current 3(Horizontal):1(Vertical) design is expected to result in stable slopes with a factor of safety of approximately 2. A stability assessment was conducted of the proposed rock walls based on the overall rock mass strength. The east wall of the proposed pit, considered to be the most critical overall slope, indicates that the wall is expected to be stable up to an overall slope angle of at least 56 degrees, even with consideration given to potential seismic acceleration effects. Kinematic failure analysis indicates a minor potential for discontinuity-based failures to occur within the desired range of overall and bench slope angles, the size and extent of which will ultimately be determined by fracture characteristics that can be monitored as mining progresses. The potential for kinematic failure is predominantly associated with the east wall of the proposed pit expansion.

Based on the information gathered for the orientations of the discontinuities, it is clear that discontinuity patterns in the Maria Pit area vary depending on location. Given the results of the kinematic failure analyses and the significant variation in dominant discontinuity orientations in the pit area, frequent observation of discontinuity trends and characteristics (dip direction, dip angle, persistence, and spacing), is recommended as mining progresses. It is also important that mine personnel utilize the results of the slope stability assessment, coupled with regular monitoring of fracture characteristics, to recognize developing potentially unstable conditions. Such circumstances may require case-by-case modifications of slope angles and bench widths to maintain safe operating conditions.

2 Background Information

2.1 Site Description

The Maria Pit is located approximately four miles northwest of Milford, Utah (see *Figure 2-1*). The existing Maria Pit and the approximate extent of the proposed pit expansion area are indicated in *Figure 2-2*. The pit area lies in the Rocky Range Mining District within a belt of altered granite to diorite intrusive rocks, and the Maria deposit is classified as a skarn copper-gold-tungsten-molybdenum type deposit. The ore zones of the Maria copper deposit are found in metasedimentary rocks located between sills or other bodies of quartz monzonite. A general geologic cross section is presented in *Figure 2-3.*

Figure 2-1: CS Mining - Maria Pit – General Location Map

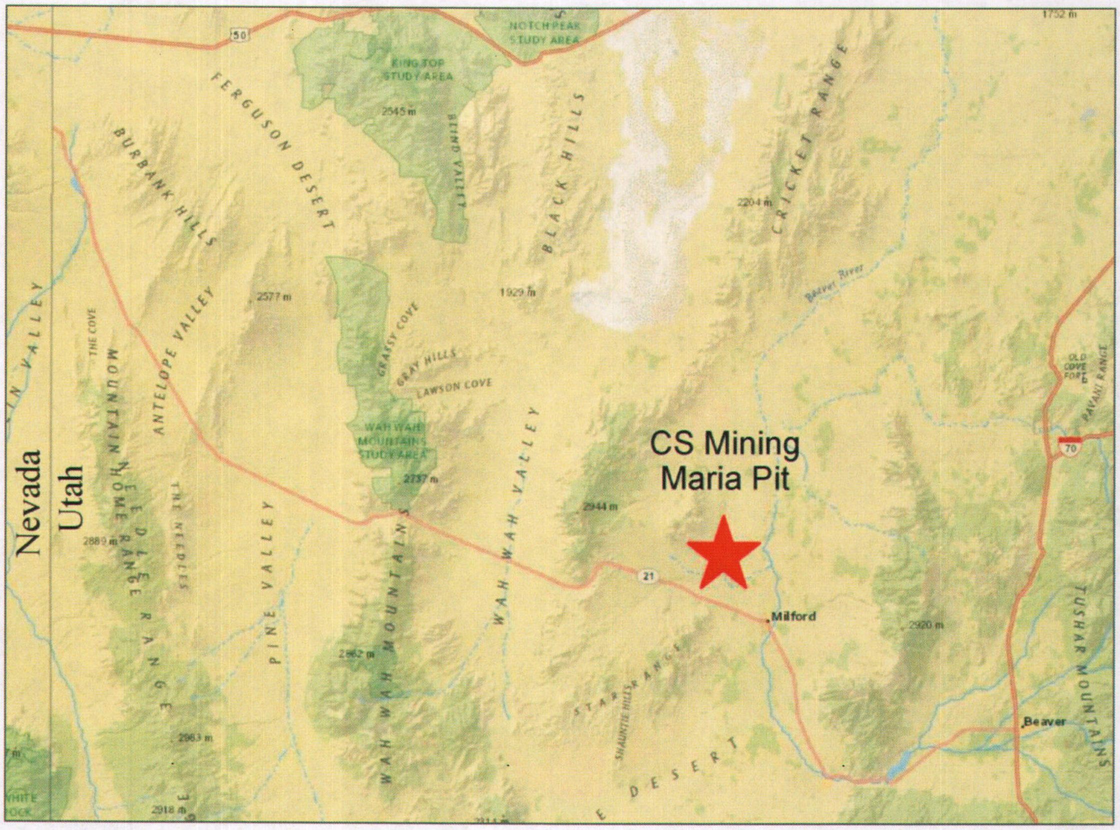


Figure 2-2: Existing Maria Pit with Cross Section Line and Exploration Hole Locations

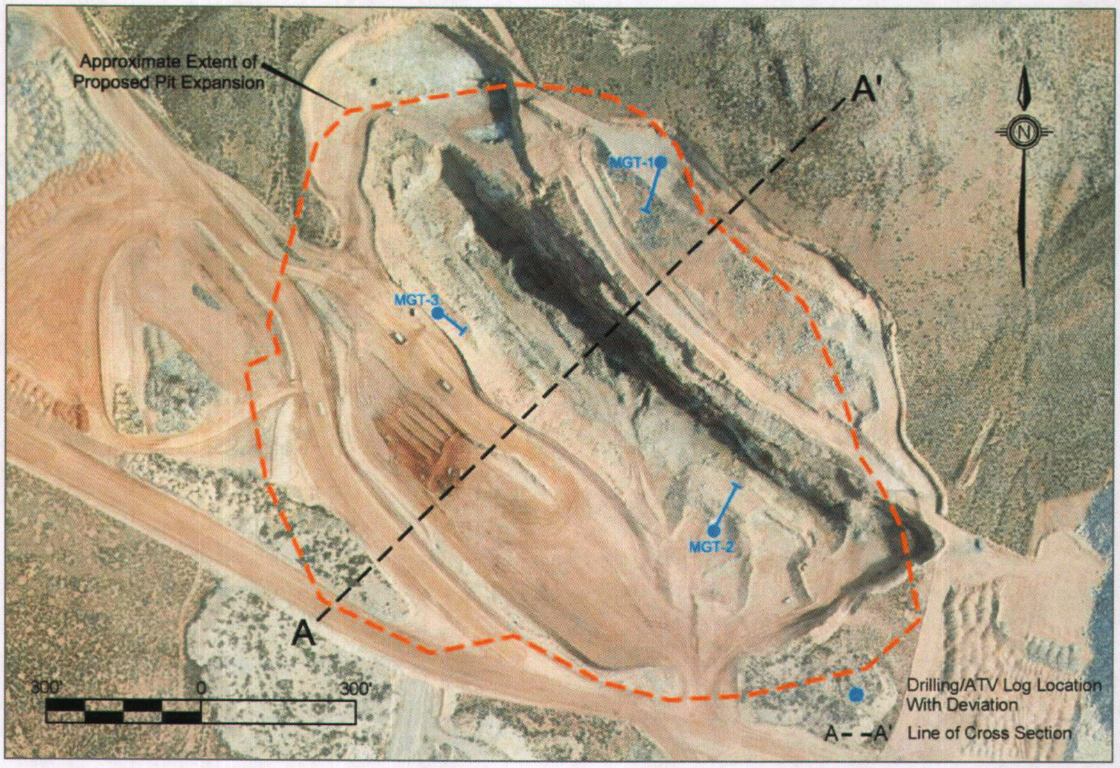
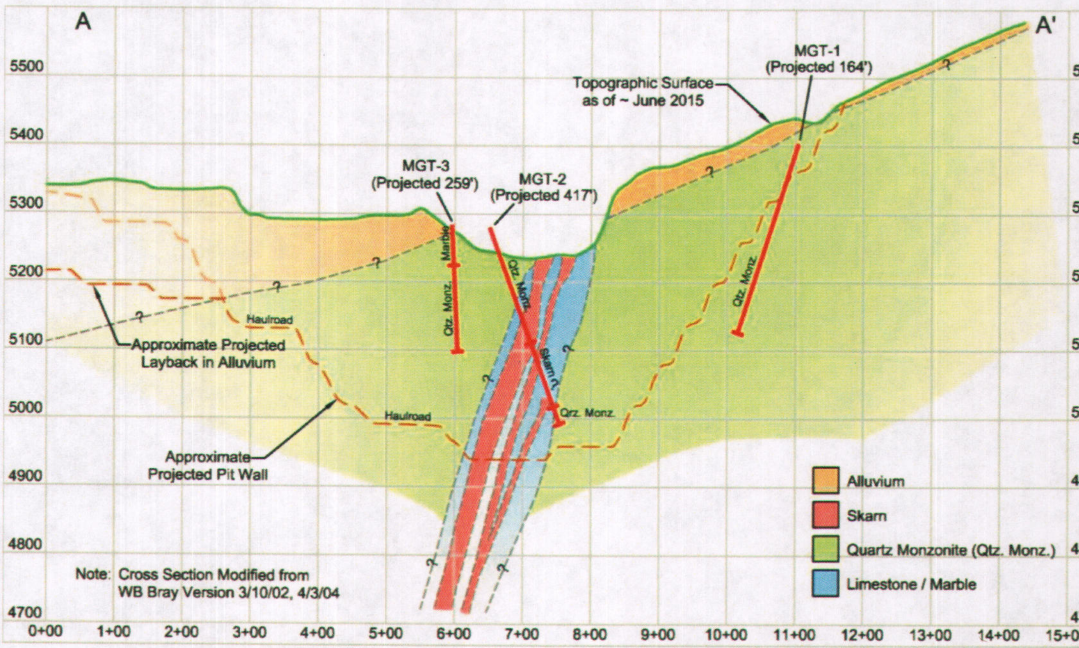


Figure 2-3: General Geologic Cross-Section A-A′ (Southwest-Northeast)



The climate of the subject area is characterized as being mostly semiarid along lower elevations to sub-humid at the higher elevations. Based on information from exploration drill holes and visual observation, the proposed pit is not expected to encounter a significant water table, even at its lowest point. In addition, CSM personnel report that there is no discharge from the current high walls or pit floor seen during or after storm events. Water that collects in the pit bottom reportedly infiltrates or evaporates within a day, depending on amount of water and weather conditions.

2.2 Data Collection Activities

The field investigation was completed between April and June 2015. Data from the field activities was used to assess the expected slope stability conditions for the proposed pit expansion. Cardno conducted geological and geotechnical field mapping, reverse circulation (*RC*) drilling, down-hole geophysical logging (acoustic televiewer and sonic), and laboratory testing of available core specimens. Cardno collected data from exposed rock in the existing pit, newly exposed areas of rock and alluvium material, and three drill holes positioned around the perimeter of the proposed pit expansion. **Cardno GLS** (a division of Cardno) collected discontinuity (fracture) data from each of the holes via down-hole geophysical methods. Acoustic Televiewer (*ATV*) and sonic logging probes were used to collect discontinuity orientation and relative rock strength information, respectively. Use of the ATV in the exploration holes is the most efficient means for collection of discontinuity data in areas of the proposed pit where no excavation has taken place. A total of 607 discontinuity orientation measurements were collected for the study via field mapping and down-hole geophysical logging.

The existing Maria pit is currently of limited size and mining was ongoing during the investigation. Data collection activities focused on safely accessible areas. As a result of ongoing production activity and in-pit traffic, available time for data collection was limited and cannot be considered exhaustive. While numerous measurements and observations were collected from the existing pit and rock exposures, much of the assessment is based on drilling and geophysical logging data from holes drilled in the areas of expected expansion.

3 Slope Stability Assessment

The slope stability assessment included analyses of slopes in both alluvium and rock. The alluvium was assessed on the basis of overall slope stability (rotational shear), and the rock was assessed for overall slope stability (rotational shear) as well as kinematic stability (wedge and planar). Both deterministic and probabilistic analyses were performed for rock slopes.

3.1 Alluvium Slope Analysis Results

Significant portions of the proposed pit walls are expected to consist of alluvial deposit material. A limit equilibrium analysis of the stability of the slopes in the alluvium was performed based on the following statements:

> Alluvium slopes will be benched to provide an average slope no steeper than 3(H):1(V);

> Total heights of alluvium slopes are not anticipated to be appreciably greater than 200 feet above bedrock elevation; and

> Appreciable groundwater seepage from the slope face has not been observed and is not anticipated in the future.

The results of the alluvium stability analysis indicate that the proposed slope configuration for benches in alluvium material should result in a safety factor of approximately 2.0, which is greater than the minimum recommended factor of safety of 1.5[1]. The stability analysis presented herein assumes no destabilizing factors related to groundwater seepage or tension cracks. The alluvium slope should be inspected routinely for evidence of groundwater seeps and tension cracks, signs that the slope may be becoming less stable. Tension cracks are only considered relevant if occurring at the top of the overall slope and relatively large, that is, indicative of a deep-seated slip surface. Tension cracks related to toppling of vertical cuts onto horizontal benches are not considered to be consequential, although they may pose a localized safety concern and should be identified as such. Appropriate surface runoff diversions is recommended,

3.2 Rock Slope Analyses Results

Stability analyses for rock slopes include both overall rock mass slope stability assessment and kinematic slope stability assessment. Both deterministic and probabilistic analyses were conducted. *Figures 3-1* and *3-2* illustrate key terminology utilized for discussing rock slope analyses.

[1] Adopted from Table 3, Engineering Manual for Slope Stability Studies, Duncan, J.M., et al., Virginia Tech Center for Geotechnical Practice and Research, 1987

Figure 3-1: Definition of Pit Wall Descriptors

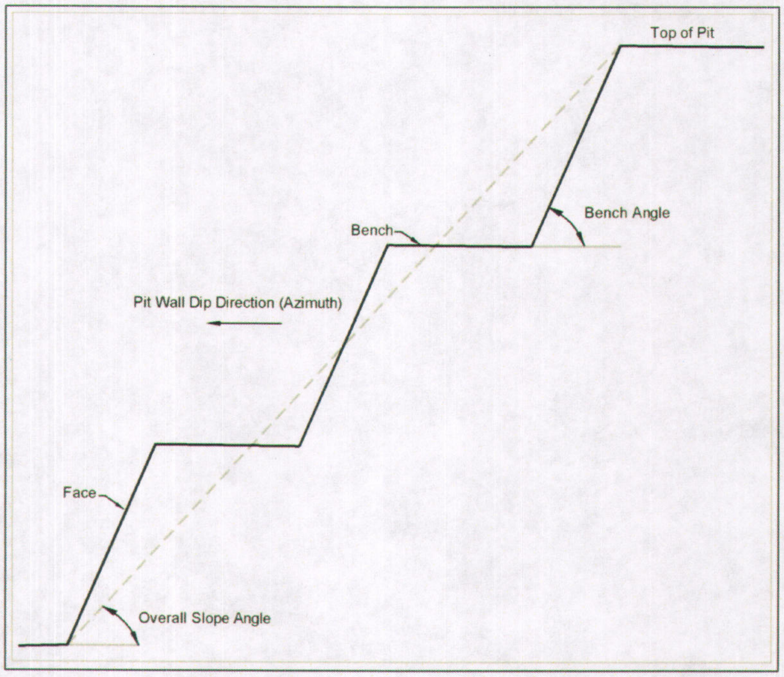
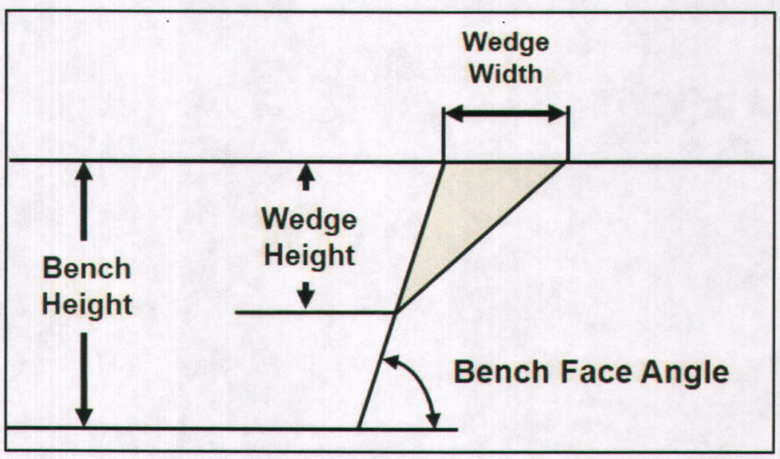


Figure 3-2: Definition of Wedge Width and Wedge Height Dimensions



3.2.1 Overall Rock Mass Slope Stability

Limit equilibrium rock mass stability analysis was used to evaluate the potential for overall slope failure in which the failure surface is controlled by the rock mass strength. The overall rock slope stability analysis focused on the east wall of the proposed pit expansion. The east slope of the projected pit will be excavated into the adjacent hillside and represents the highest and steepest overall rock slope to be excavated. The west side of the proposed pit contains the same rock type as the east side, but the rock joint planes dip to the west and also contains a fair amount of alluvium. The overall slope of the west side is also generally less steep as a result of the haul road layout. The eastern slope has the greatest potential to be adversely affected by the orientation of the prevailing joint sets.

As the eastern slope is considered to be the most critical rock slope of the pit the overall pit slope stability analysis for the east slope is considered to be the worst-case conditions expected for overall slope stability.

The quartz monzonite intrusive rock present in the east slope exhibits different degrees of fracture density. As a result, variable analyses were conducted based on intact rock and fractured rock characteristics. The overall rock mass characterization completed for this assessment takes into account compressive strength of the rock, Rock Quality Designation, discontinuity spacing and aperture, joint roughness, infilling, and weathering. Rock Mass Rating (*RMR*) classification for the rock in the eastern wall ranges from fair to very good. Geological Strength Index characterization ranges from fair to good. Discontinuity orientation in relation to the proposed pit wall angles was also taken into account.

Based on the overall rock stability analysis and the rock mass conditions of the area, the east slope of the mine exhibits factors of safety ranging from 1.79 to 3.45, depending on the RMR classification utilized (above the recommended minimum of 1.3 to 1.5) with a general pit slope inclination of around 56 degrees. Considering potential seismic effects, the overall slope assessment results in factors of safety ranging from 1.58 to 3.10 (well above the recommended minimum of 1.1 under seismic conditions). Probability analysis for overall rock slope stability indicates a very low probability of failure for overall slope angles up to 56 degrees.

Water table and water pressures have not been considered in the overall slope stability analysis since the rock mass has been found to be dry and the water table is far below the final excavation depth of the proposed slopes.

3.2.2 Kinematic Slope Stability

Kinematic stability analyses were conducted based on discontinuity information collected from field observations and hole logging using an Acoutic Televiewer (*ATV*) downhole tool to profile all fractures incluing inclination and orientation. The evaluation of the proposed pit slopes includes assessment of susceptibility to plane and wedge failures. The potential for both of these types of failures was identified during field observations. Both deterministic and probabilistic kinematic analyses have been conducted for evaluation of the Maria pit slopes. Planar and wedge failure analyses were performed utilizing modeling software by **Rocscience Ltd.** The proposed pit design includes benches 60-feet high and 20-feet wide. The kinematic analyses considers overall pit slope angles ranging from 50 to 56 degrees and bench slope angles ranging from 60 to 66 degrees. Overall slope analyses assume a maximum overall pit slope height of 390 feet.

Noticeable differences in dominant discontinuity orientations exist in the footwall, the ore body, and the hanging wall. Therefore, different areas of the proposed pit were evaluated based on the most likely discontinuity trends for each area. Joint persistence, or the approximate distance that an individual joint typically extends within the rock mass, plays a significant role in determining the size of potential kinematic failures. Due to the limited existing rock exposure at the Maria pit, the available data only allows for general estimation of persistence. During expansion of the Maria pit, it will be important to monitor the persistence of key discontinuities in order to update analysis of the kinematic stability of the slope. Joint spacing also plays a significant role in determining the size of potential wedges for the proposed pit expansion.

The following statements summarize the results of the kinematic stability assessment. *Figure 3-3* shows the locations of the discrete slopes analyzed and the corresponding geologic data.

> The east wall of the proposed pit (Slopes A through D) is expected to have the greatest potential for planar and wedge failures. Planar failures located in the east wall are associated with two different joint sets. Nearly all the potential wedge failures in the eastern wall are associated with joint combinations containing a high-angle joint set that is very abundant in the existing pit walls. Wedge failures in the east wall are generally expected to be approximately 10 tons or less. Distribution of discontinuity sets in the east wall is shown by the stereonet in *Figure 3-4*.

> Potential planar failure exists in Slopes K and L in the northwestern portion of the proposed pit due to the presence of a single joint set. In addition, wedges with high probability of failure exist within Slopes J, K, and L. The wedges are generally expected to be 10 tons or less. Distribution of discontinuity sets in the northwest wall is shown by the stereonet in *Figure 3-5*.

> No significant planar wedge failures are expected in the southwestern portion of the proposed pit (Slopes F through I).

> Based on field observations of joint spacing and persistence within the available pit exposure, all wedges are generally expected to be 10 tons or less. In the event that joint conditions change significantly from that observed in the existing pit, potential wedges in Slopes A through D and Slope J could become more problematic.

> In general, there is more potential for wedge failure at the higher angle range associated with bench slopes (slopes greater than 60 degrees).

Figure 3-3: Delineation of Projected Pit Wall Areas (Design Sector Layout)

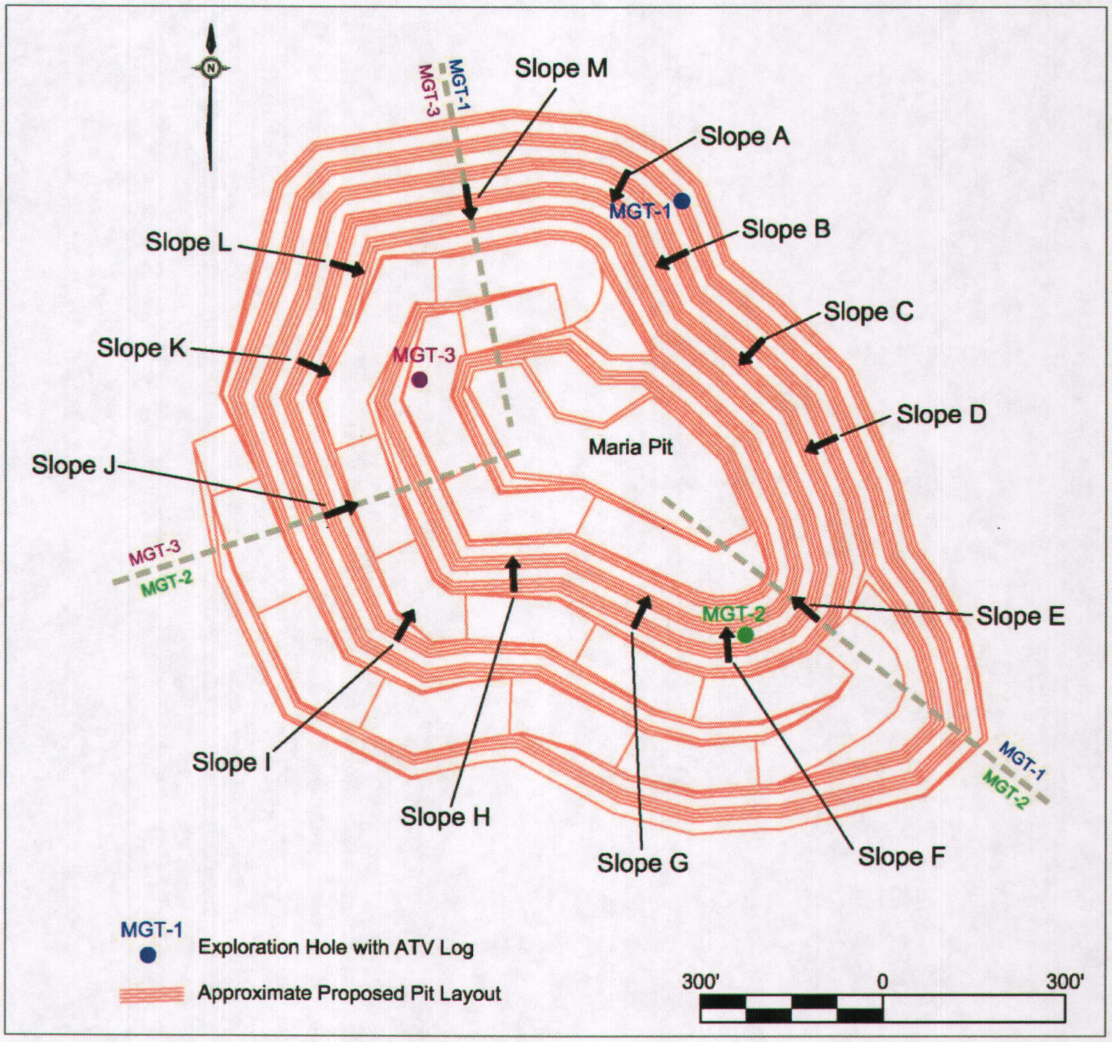


Figure 3-4: Stereonet Identifying Discontinuity Sets in East Wall (MGT-1)

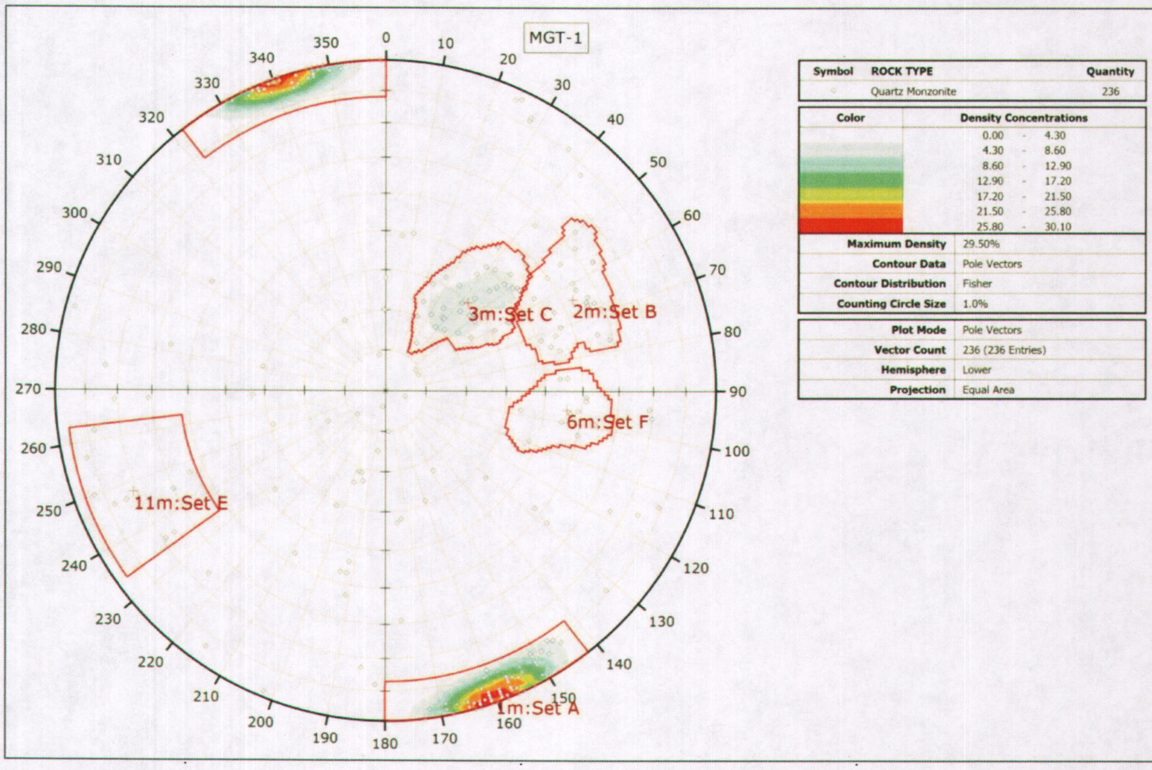
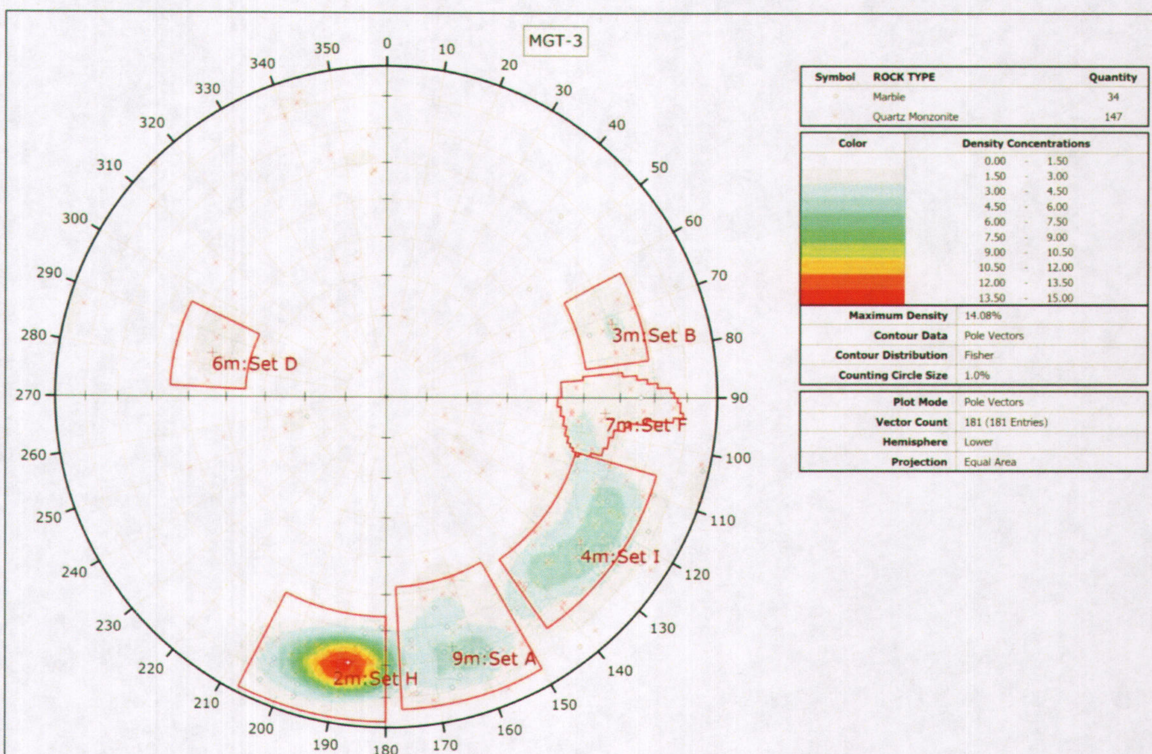


Figure 3-5: Stereonet Identifying Discontinuity Sets in Northwest Wall (MGT-3)



The effects of water pressure and seismic acceleration were not considered for the analyses. Both factors would be expected to decrease the safety factors of individual sliding blocks and wedges, the consequences being variable based on the beginning factor of safety and the expected size of the wedge. In general, due to the site environment and the depth of the water table, water pressure is not expected to play a major role with regard to potential planar and wedge failures. As mining progresses, more detailed analysis of certain areas of the pit may be warranted.

3.3 Conclusions and Recommendations

3.3.1 Conclusions

The results of the slope stability assessment identify areas of the pit that are most susceptible to potential instability. The pit walls of the proposed expansion will consist of both alluvium and rock. The results of the stability analyses performed for this assessment indicate the following four main conclusions:

1. Stability of slopes in alluvial material is expected to be satisfactory (factor of safety = 2.0) based on the proposed plan to utilize an average slope no steeper than 3(H):1(V).
2. Overall pit slopes in rock are expected to be stable, in terms of overall rotational shear failure, at or below overall pit slope angles of 56 degrees (even with consideration of potential seismic effects).
3. In some areas, especially in the east wall of the proposed pit, while the overall pit wall is expected to be stable, planar and/or wedge kinematic failure potential exists. The size of the potential planar and wedge failures is dependent upon joint spacing and joint persistence, the latter of which is difficult to estimate given the limited extent of the current pit.
4. The east wall of the pit is considered the most critical area of the proposed expansion with regard to overall and kinematic slope stability.

3.3.2 Recommendations

- During mining, as-necessary modification of slope angles and bench widths to accommodate newly exposed fracture characteristics, most notably persistence of key joint sets, is recommended. The results of the pit slope stability assessment provide guidance as to key discontinuity orientations and characteristics that should be monitored. The purpose of during-mining modifications would be to avoid or minimize the opportunity for kinematic failures, or minimize the size and extent of potential failures on a case-by-case basis.
- Regular joint mapping by mine personnel is strongly recommended in order to update stability analysis with the dominant fracture patterns in each pit wall, as the most likely mode of failure in the pit is expected to be discontinuity-controlled. It is not uncommon for open pit mines to experience periodic kinematic failures, especially in areas that contain numerous geologic structural features. The effect of the kinematic failures must be considered with regard to size, and location within the pit.
- Frequent cleaning of debris from benches is recommended.
- Isolated fracture zones may have the potential to exaggerate the impact of certain discontinuity sets on slope stability. Delineation of specific fracture zones within pit walls may be necessary for future detailed pit design.
- Although the mine area is not prone to significant precipitation and the proposed pit is not expected to be impacted by the local groundwater table, especially if small draws on the eastern hillside are intercepted as the pit is enlarged, capture and rerouting of storm water away from the edges of the pit walls is highly recommended. In addition, any areas of groundwater seepage that may develop as the pit deepens should be monitored and, in the event they become significant, incorporated into future stability analysis.
- Key mine personnel should be able to visually identify obvious potential planar or wedge failures in the pit walls.
- Under no circumstances, should excavation activities result in overhanging pit walls.

The current evaluation and results are predominantly based on information from three exploration holes and observations collected from the relatively small existing Maria pit. It is very important that the condition of the benches is constantly evaluated as mining progresses and as discontinuities and related features are exposed. This assessment does not address stability issues relative to large fault zones. Analysis and recommendations for design around such features requires very specific information and must be considered on a case-by-case basis. If such a feature is encountered during mining, a separate investigation is strongly recommended.

The analyses conducted for this assessment are based on industry standard practices and methodologies. Our professional services have been performed using that degree of care and skill ordinarily exercised under similar circumstances by reputable engineering consultants practicing in this or similar localities. No other warranty, either expressed or implied, is made as to the professional advice included or intended for this analysis. We strongly recommend that observation and monitoring of the discontinuities encountered during continued excavation and pit wall conditions be incorporated into the regular routine of mine personnel. Regular monitoring will enhance the understanding of the currently known discontinuity patterns and allow for recognition of changes in discontinuity trends and wall stability as mining progresses.